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ABSTRACT

Eighty-seven problems are included in this volume which is arranged to match study segments 2 through 14. The subject matter is related to projectiles, simple harmonic motion, kinetic friction, multiple pulley arrangements, motion on inclined planes, circular motion, potential energy, kinetic energy, center of mass, Newton's laws, elastic and inelastic collisions, Kepler's laws, universal gravitational constants, planetary orbits, and escape speeds. Also included are study guides for the problem set. (Related documents are SE 016 065 - SE 016 088 and ED 062 123 - ED 062 125.) (CC)

UNITED STATES NAVAL ACADEMY

Self-Paced PHYSICS

U. S. NAVAL ACADEMY
EX SCIENTIA TRIDENS

SEGMENT 18

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STUDY GUIDE

SELF-PACED PHYSICS

P	STEP	NAME	P	STEP	SECTION SEGMENT 18
1		A B C D	9		(ans)
2		A B C D	10		(ans)
3		A B C D	11		(ans)
4		(ans)	12		(ans)
5		A B C D	13		(ans)
6		A B C D	14		(ans)
7		(ans)	15		(ans)
8		(ans)	16		(ans)

STUDY GUIDE

SELF-PACED PHYSICS

P	STEP	NAME	P	STEP	SECTION SEGMENT 18
17		(ans)	26		(ans)
18		A B C D	27		(ans)
19		(ans)	28		(ans)
20		(ans)	29		(ans)
21		(ans)	30		A B C D
22		(ans)	31		A B C D
23		(ans)	32		A B C
24		A B C D	33		(ans)
25		(ans)			

P	STEP	NAME	P	STEP	SECTION
34		A B C D	43		A B C D
35		A B C D	44		(ans)
36		(ans)	45		(ans)
37		(ans)	46		A B C D
38		(ans)	47		(ans)
39		(ans)	48		A B C D
40		(ans)	49		A B C D
41		(ans)	50		A B C D
42		(ans)	51		(ans)

P	STEP	NAME	P	STEP	SECTION SEGMENT 18
52		(ans)	61		A B C D
53		(ans)	62		A B C D
54		(ans)	63		(ans)
55		(ans)	64		A B C D
56		(ans)	65		A B C D
57		(ans)	66		A B C D
58		(ans)	67		(ans)
59		(ans)	68		A B C D
60		(ans)	69		(ans)

P	STEP	NAME	P	STEP	SECTION SEGMENT 18
70		A B C D	79		(ans)
71		A B C D	80		A B C D
72		A B C D	81		(ans)
73		(ans)	82		A B C D
74		A B C D	83		A B C D
75		(ans)	84		A B C D
76		(ans)	85		(ans)
77		(ans)	86		(ans)
78		(ans)	87		(ans)

1 (2). A perfectly elastic ball is thrown against a vertical wall with speed v, and rebounds with the *same* speed v.

A. The acceleration is not zero, because the direction of motion of the ball changed.

B. The acceleration is not zero, because the position of the ball is changed.

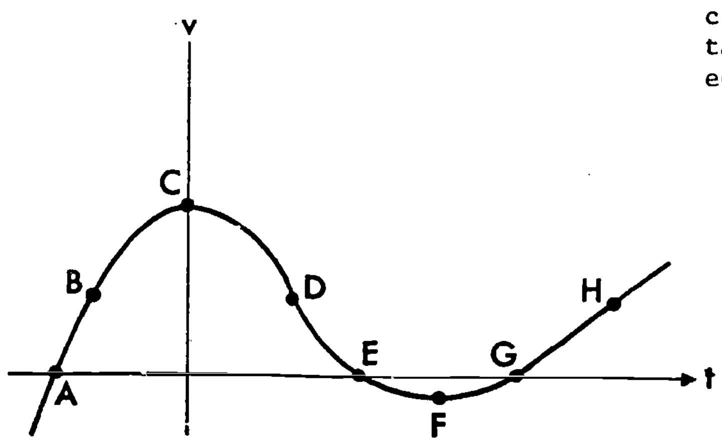
C. The acceleration is zero, because the direction of motion of the ball changed.

D. The acceleration is zero, because the speed of the ball is unchanged.

2 (2). A falling tennis ball strikes the floor vertically with a speed of 16 ft/sec and rebounds upward at 14 ft/sec. The ball was in contact with the floor for 0.01 seconds. What was its average acceleration during contact?

A. 200 ft/sec^2, directed upward
B. 200 ft/sec^2, directed downward
C. 3,000 ft/sec^2, directed upward
D. 3,000 ft/sec^2, directed downward

3 (2).



In the figure, the velocity of a particle is plotted as a function of time. From the given choices, select the answer containing points which indicate equal acceleration.

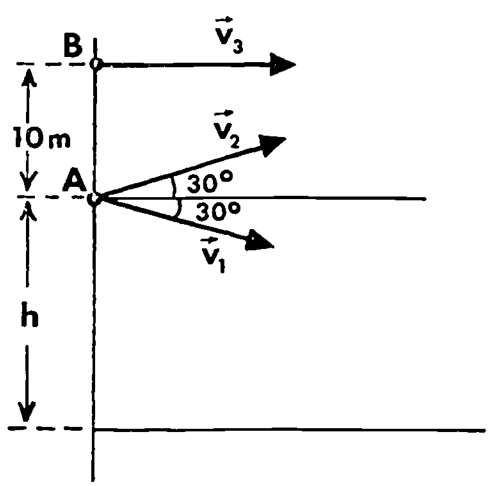
A. B, D and H
B. A, E and G
C. B and D
D. C and F

4 (2). The position of a particle can be described by the equation

$$X = A \sin (\phi - \omega t)$$

where A is a constant equal to 10 m, ϕ is an angle equal to $5\pi/6$ radians, and ω represents some angular speed and is equal to 2π radians/sec (dimensions T^{-1}). Find the acceleration of the particle at t = 1 sec. (HINT: 2π radians $\equiv 360°$.)

5 (3).



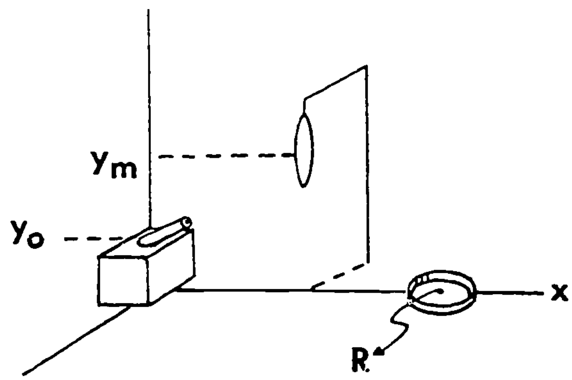
Two balls, 1 and 2, are projected from point A (see figure) each with initial speed of 28 m/sec and directions as shown in the figure. A third ball, 3, is projected from point B, located 10 meters above A, with a horizontal velocity of 28 m/sec. The ball(s) hitting the ground with the greatest *vertical* component of velocity is (are):

A. 1
B. 3
C. 1 and 2 (equal)
D. 1, 2, and 3 (equal)

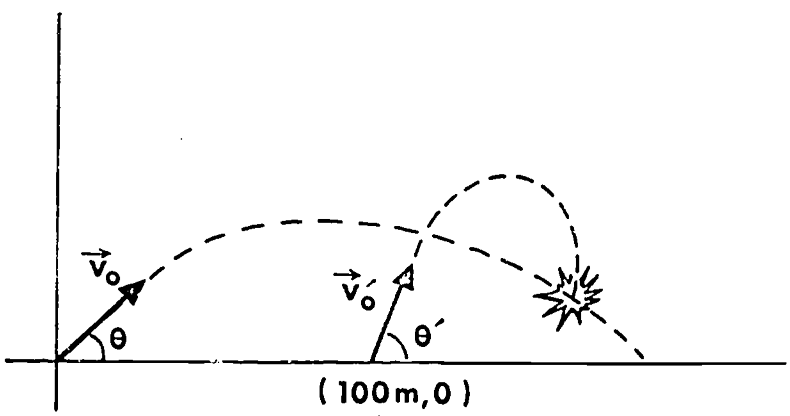
6 (3). Two balls, 1 and 2 are projected from point A (see above figure) with initial speed of 28 m/sec and directions as shown. A third ball, 3, is projected from point B, located 10 meters above A, with a horizontal velocity of 28 m/sec. The ball(s) hitting the ground last is (are):

A. 3
B. 2 and 3 (simultaneously)
C. 2
D. 1, 2, and 3 (simultaneously)

7 (3). A human cannonball is shot out of a cannon, through a hoop and into a pool of water. Assume that the "cannonball" reaches the highest point of his trajectory at the hoop. Given that R = 120 ft, y_m = 121 ft, and y_o = 40 ft, compute the initial velocity of the "cannonball".



8 (3). A particle is projected from the origin with an initial velocity of 40 m/sec, at 37° above the horizontal. At the same time a second particle is projected from the point (100 m, 0) with an initial velocity $\vec{v}'_o$. After 4.55 seconds the two particles collide in midair. Determine $\vec{v}'_o$.

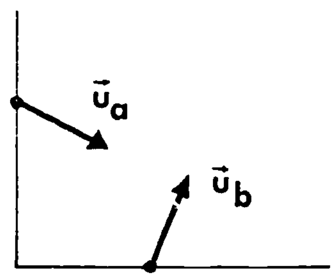


9 (3). A particle starts from rest with an initial acceleration of 2 m/sec^2. Its velocity is given as a function of time by the equation

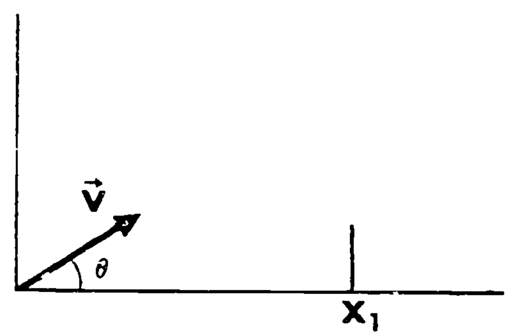
$$v = \alpha + \beta t + \gamma t^2$$

At the end of the 5th second its velocity is 15 m/sec. How far does it travel during the first minute?

10 (3). Particles a and b are projected at $t = 0$, as shown in the figure. If we let $\vec{u} \equiv \vec{v}_o$, the initial velocities are $(u_{ax}, u_{ay}) =$ (20 m/sec, -10 m/sec) and $(u_{bx}, u_{by}) =$ (5 m/sec, 20 m/sec). The initial positions are $(x_{ao}, y_{ao}) =$ (0, 20 m) and $(x_{bo}, y_{bo}) =$ (10 m, 0).



11 (3). A projectile is shot from a point on a flat plain and just clears a 10-foot fence a distance x_1 away. If $x_1 = 125$ ft and $\theta = 30°$, where does the projectile land?



12 (3). A cannon can project a shell with an initial speed of 500 ft/sec. Assume that the shell leaves the cannon at ground level and lands 4685 ft away; find the angle above the horizontal at which the shell was fired.

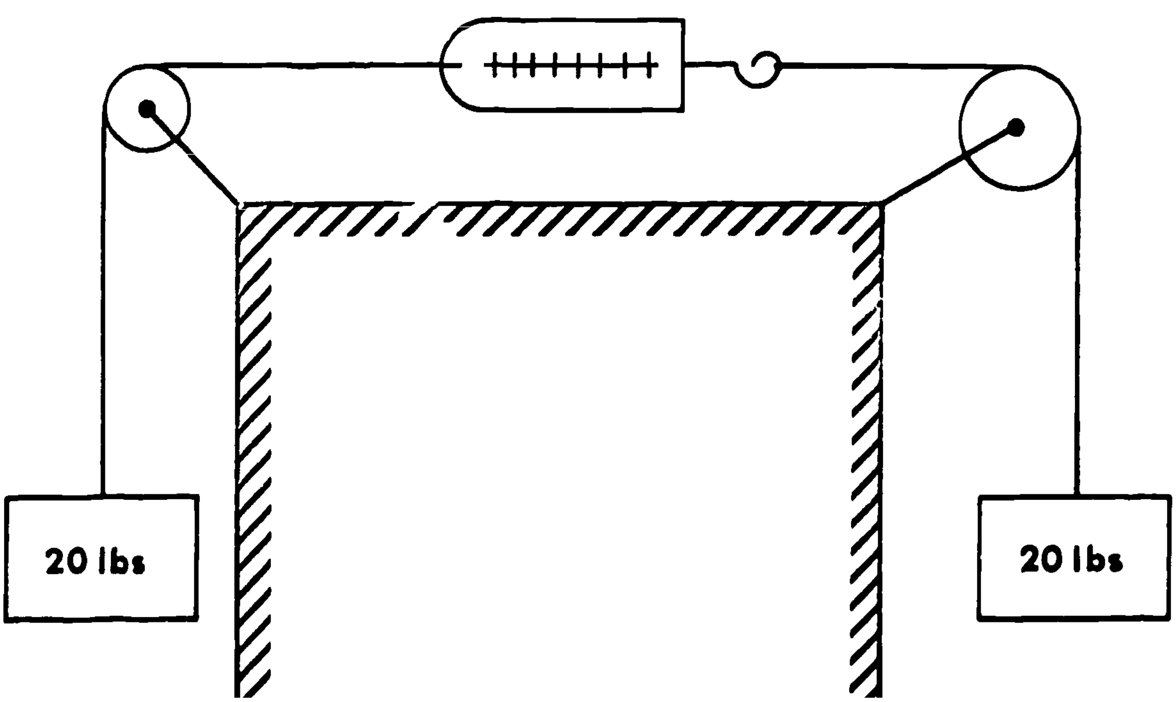
13 (3). An object with an initial speed of 100 m/sec is subject to a deceleration proportional to its speed. The proportionality constant is $k = 0.51\ \text{sec}^{-1}$. How far does the object travel in 4 seconds?

14 (3). A ball is dropped from a certain height with zero initial velocity. If the ball is subject to an acceleration $\vec{a} = \vec{g} - k\vec{v}$, with $k = .12\ sec^{-1}$, what will be its speed at the end of the 10th second?

15 (3). An object is projected from ground level vertically upward, with an initial speed of 100 m/sec. The air resistance results in a deceleration proportional to the velocity, with proportionality constant $k = 0.2\ sec^{-1}$. How long does it take the object to reach its highest point and what is its total time of flight?

16 (3). A projectile is fired from ground level with an initial speed of 200 ft/sec at an angle θ above the horizontal. In addition to gravity it is subjected to an acceleration $\vec{a}_r = -k\vec{v}$, with $k = 0.12\ sec^{-1}$, resulting from the air resistance. At $t = 10$ sec it hits the ground at a horizontal distance of 700 ft from its starting point. At what time did the projectile reach its highest point?

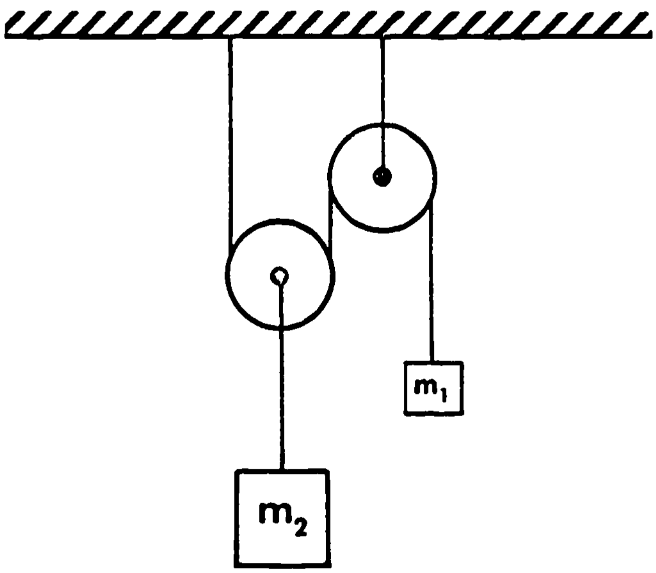
17 (4). Two stationary 20-lb blocks are shown attached to a spring balance. The string connecting each block to the balance is massless and the pulleys (different radii) are also massless as well as frictionless. What is the reading on the spring balance?



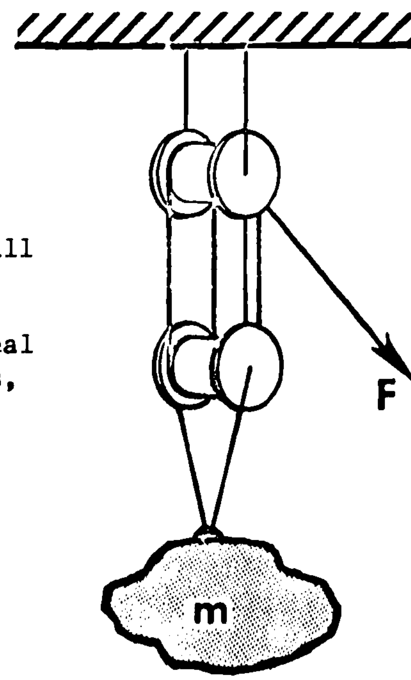
18 (5). Kinetic frictio

A. Depends on the area of surface contact.
B. Is independent of the area of surface contact over wide limits.
C. Depends on the shape of the area.
D. Depends on the speed with which surfaces move.

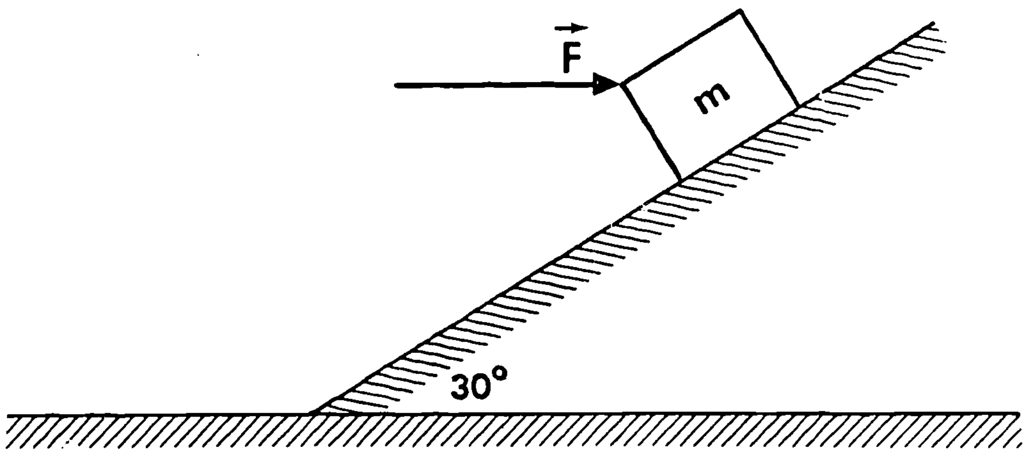
19 (5). In the diagram, two pulleys are shown each with a block attached. The pulleys and string are assumed to be massless, and there is no friction in the bearings (ideal conditions again). If m_1 is 10 kg and m_2 is 30 kg, what is the acceleration of block two?



20 (5). Consider the multiple pulley arrangement shown. How large a force will be required to lift a 300-lb automobile engine at constant velocity with this block and tackle? (Let's assume the ideal conditions of massless ropes and pulleys, and neglect friction.)

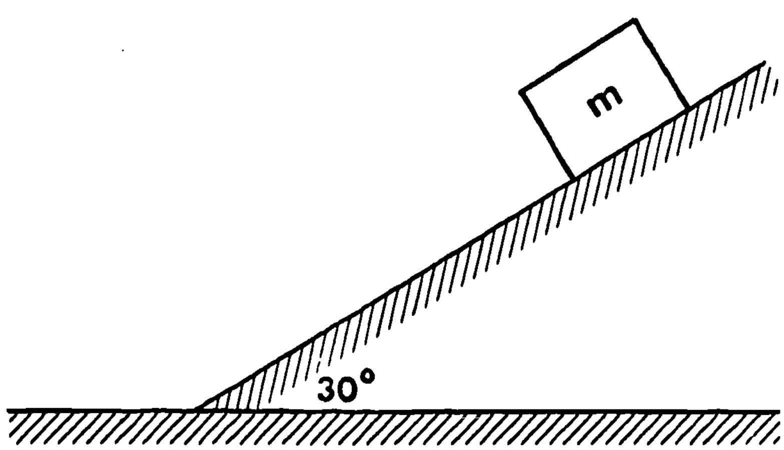


21 (5). A force of 20 nt parallel to the horizontal is shown pushing a 3-kg block up an inclined plane. If the coefficient of kinetic friction (μ_k) is equal to 0.05, what is the force of friction?



22 (5). The longest runway at National Airport in Washington, D. C. is 6870 ft. Departing jet aircraft can allow only 3000 ft for take-off in order to clear obstacles at the end of the runway. A fully loaded Boeing 727 weights 100 tons (2000 lb = 1 ton) and has a take-off speed of 120 mi/hr. What constant force must be generated by the jets for take-off?

23 (5). A 20-kg block starts from rest down the inclined plane (see diagram). If μ_k = 0.1, and if the block begins at a vertical height of 2 m, how long will it take to reach the bottom of the inclined plane?



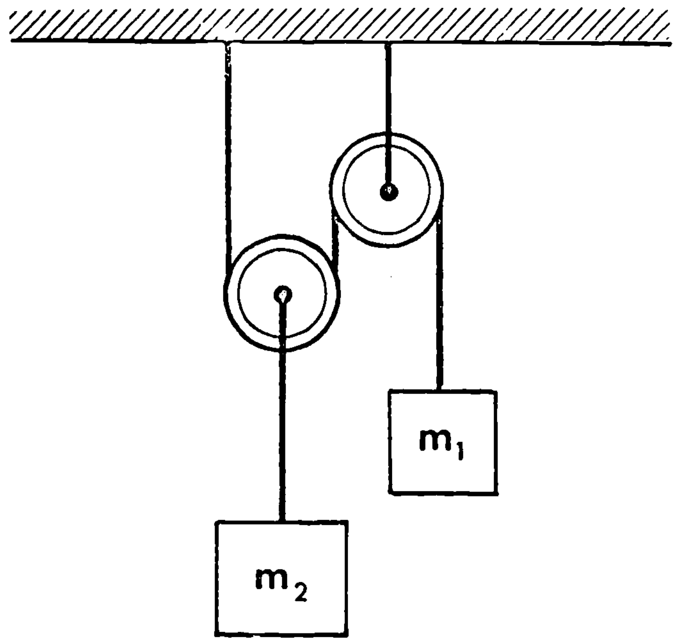
24 (5). In the diagram below, two pulleys are shown hanging from the ceiling. Assume m_1 descends at a constant velocity v_1, what is the velocity of m_2?

A. $2\ v_1$ up

B. $\frac{1}{2}\ v_1$ downward

C. $\frac{1}{2}\ v_1$ upward

D. $2\ v_1$ downward



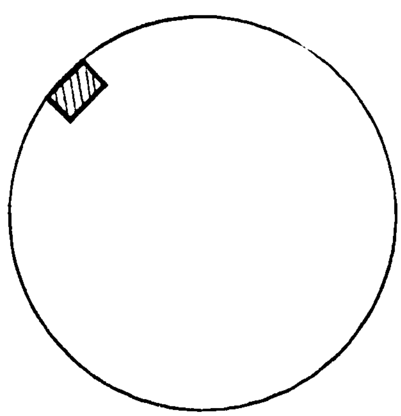
25 (6). An airplane is making a very steep turn (70 degrees, angle of bank). What is the apparent weight of the pilot, or in other words, with what force does the cockpit seat push on the pilot? (Pilot's mass is 70 kg).

26 (6). A boy swings a sling shot in a *vertical* circle with a radius equal to one meter. If the boy can turn the sling at 60 RPM, what is the maximum horizontal range of his sling shot?

27 (7). A block weighing 16 lb is initially at rest. It is made to move through a distance of 100 ft in 10 sec by a constant force. How much work must have been done?

28 (7). A 10-kg block rests on a horizontal floor. The coefficient of kinetic friction between the block and the floor is 0.2. A constant horizontal force of 100 nt is now exerted on the block and it starts sliding. What is the instantaneous power supplied by the force at the end of the 5th second after the force is applied?

29 (7). A 5-kg block is moving around a circular loop in a spaceship ("weightless"). If the coefficient of kinetic friction between the loop and block is 0.2 and the loop has a diameter of [illegible]m, how much work must be supplied to the block per revolution in order for it to move with a constant speed of 10 m/sec?



30 (8). The potential energy of a nucleon in a nucleus is sometimes given as $U = -\frac{k}{r} e^{\quad r}$ with k and μ positive constants and r the distance from the center of the nucleus. What is the force on the nucleon as a function of r?

A. $\frac{k}{r} e^{-\mu r} \left(\frac{1}{r} + \mu \right)$

B. $- \frac{k}{r} e^{-\mu r} \left(\frac{1}{r} + \mu \right)$

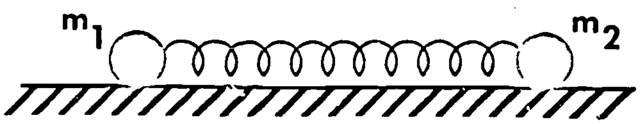
C. $\frac{k\mu}{r} e^{-\ r}$

D. $- \frac{k}{r^2} e$

31 (8). A mass attached to a spring slides back and forth on a frictionless surface. the center of its motion, its kinetic energy is equal to 1.28 J. If mass-spring system is left undisturbed, which one of the following kinetic energy values will the mass never attain?

A. 0 J
B. 1.73 J
C. 0.005
D. 1.25 J

32 (8). Two masses, m_1 and m_2, are connected by a spring. Both masses rest upon a horizontal frictionless plane and the system moves in one dimension, undergoing both vibration and translation.



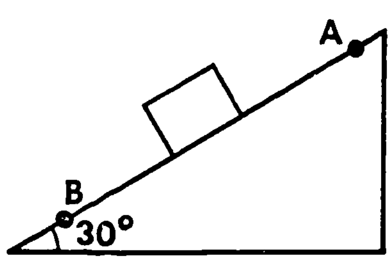
Masses m_1 and m_2 have velocities v_1 and v_2 with respect to an observer at rest, relative to the plane. Calculate the *difference* between the total energy as seen by a "rest observer" and the total energy as seen by an observer moving with constant velocity $-u$ relative to the rest frame. (Note that the velocity vectors have been written in scalar form since the motion is in one dimension.)

A. $(m_1 + m_2)\ u^2$

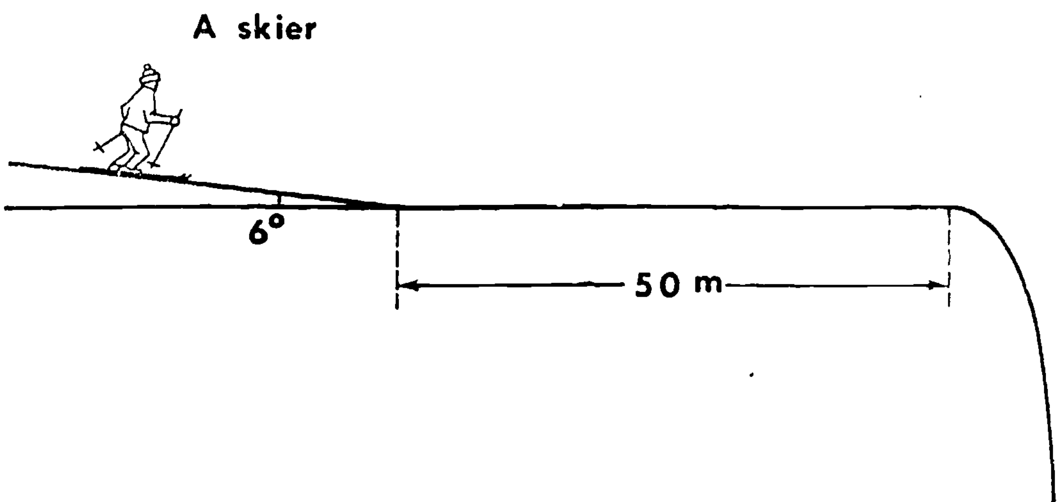
B. $(m_1v_1 + m_2v_2)\ u + (1/2)\ (m_1 + m_2)\ u^2$

C. $(m_1 + m_2)\ (v_1 + v_2)\ u + (1/2)\ (m_1 + m_2)\ u^2$

33 (8). A 4-kg block slides down a 30° inclined plane. The block's speed at point A is 1 m/sec, and at B it is 3 m/sec. If the distance from A to B along the incline is 2 m, what is the work done by friction between points A and B?



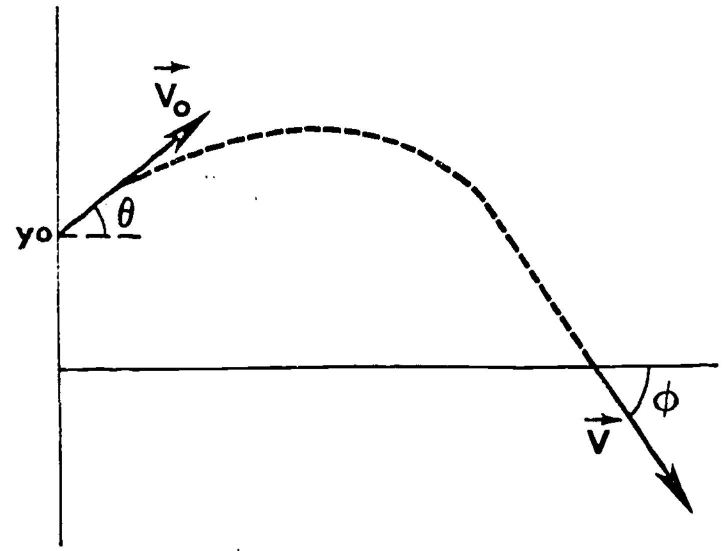
34 (8).



A student skier (who can only schuss) finds himself traveling straight down a 6° slope at a constant speed of 10 m/sec. At the foot of the slope there is a 50 m level stretch followed by a dangerous drop. Without braking (he doesn't know how) or ditching, where will the skier come to rest? (Neglect air resistance.)

A. at the foot of the slope
B. on the level stretch 5.1 m from the foot of the slope
C. 1.5 m before the drop
D. at the bottom of the drop

35 (8). A projectile is shot from a height y_o = 1 ft, with an initial v_o = 6 ft/sec, and an angle θ = 37°. Neglecting air resistance, what is the projectile's velocity when it hits the ground?



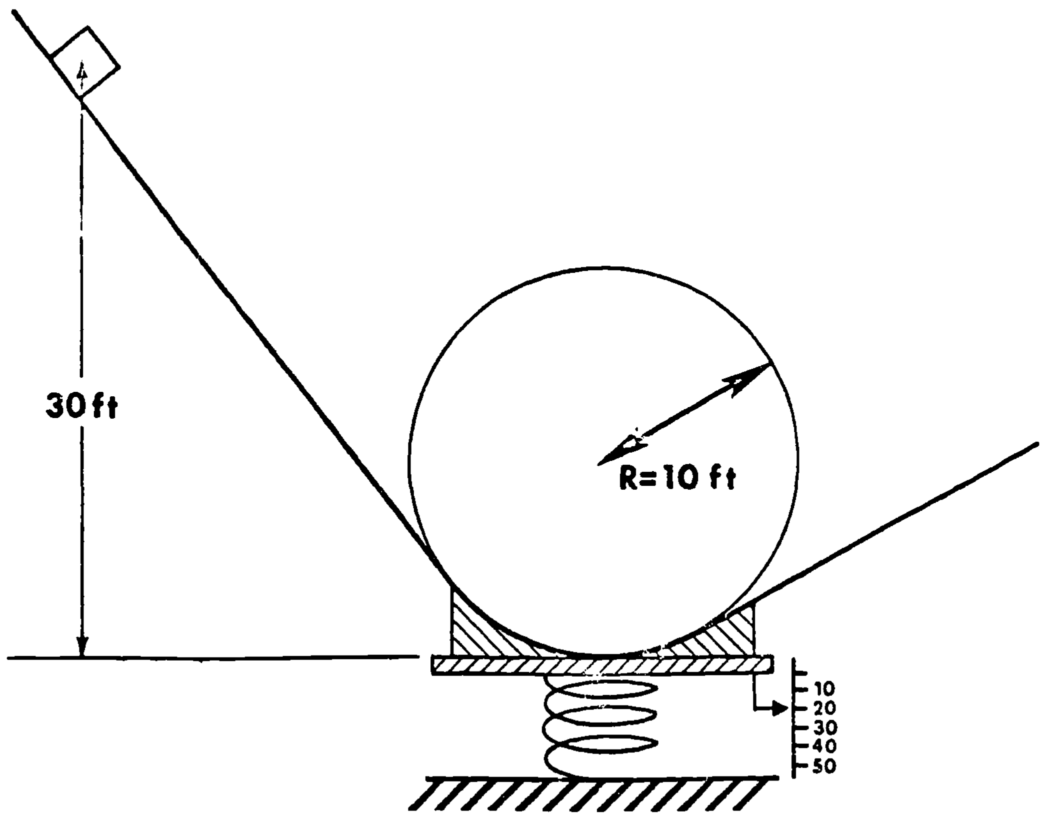
A. v = 10 ft/sec; ϕ = 61.3°

B. v = 8.77 ft/sec; ϕ = 61.3°

C. v = 8.77 ft/sec; ϕ = 56.8°

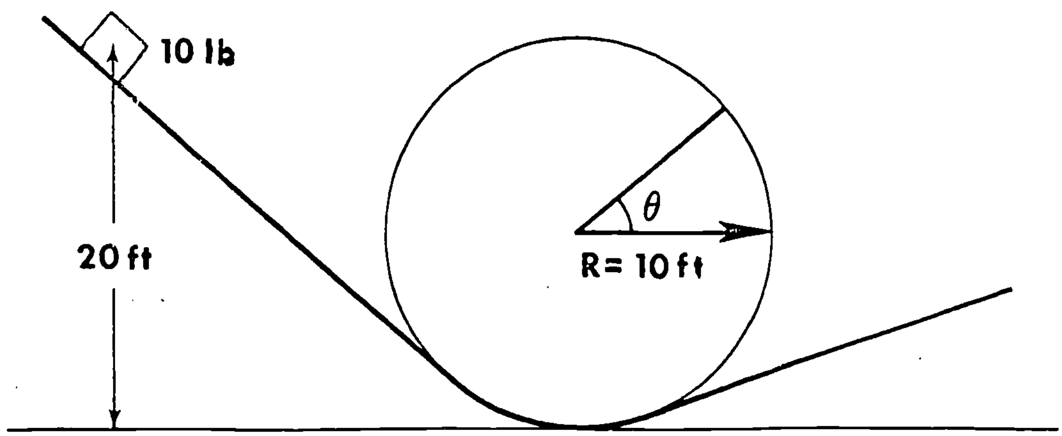
D. v = 6 ft/sec; ϕ = 37°

36 (8).



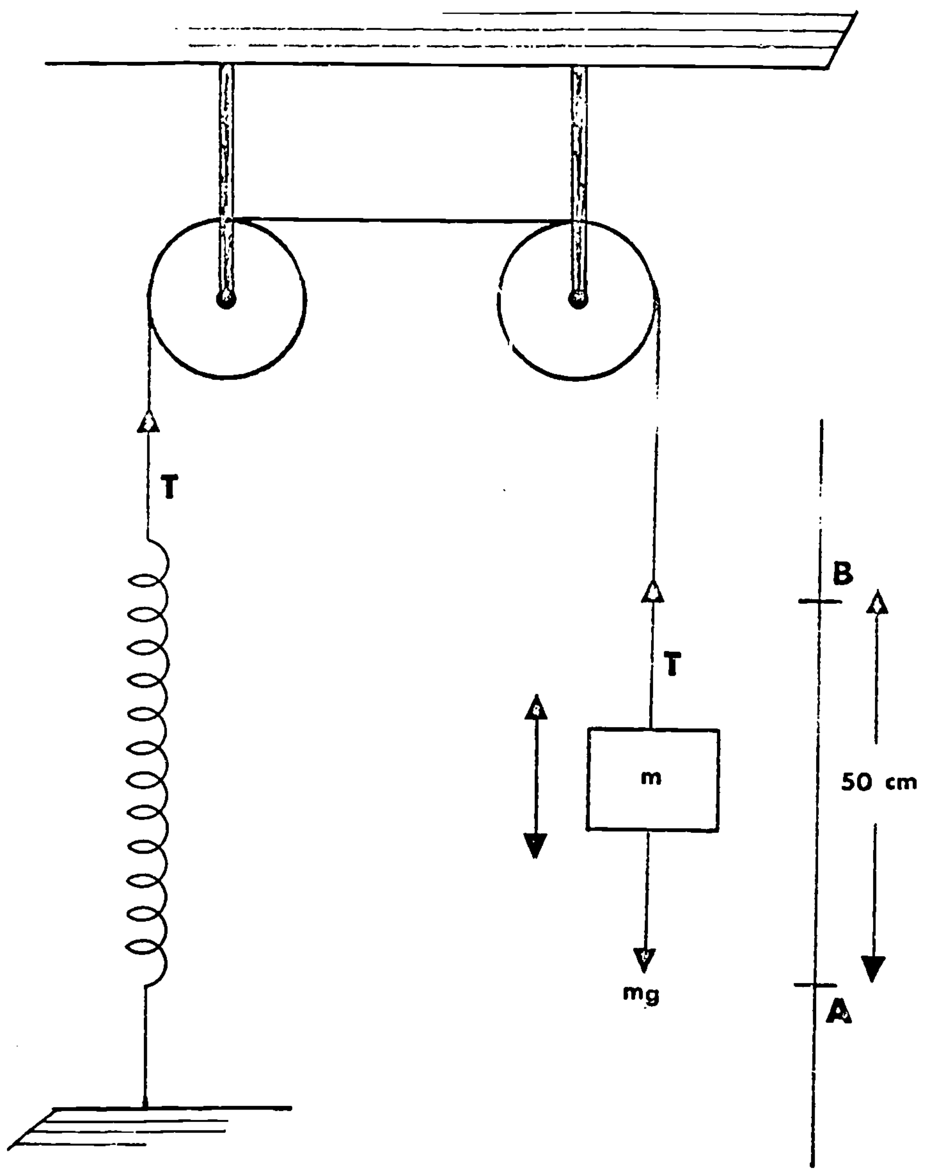
A frictionless looped track, with a radius of 10 ft, is attached to a spring balance calibrated to read directly in pcunds. When the 10-lb block is at rest, 30 ft above the bottom of the loop, the balance reads 20 (assume the balance plate can only move vertically - no tilting). What are the readings of the balance, when the block is at the bottom and the top of the loop, respectively?

37 (8).



A 10-lb block starts from rest at a point 20 ft high, and slides on the frictionless looped track shown above. At what point on the circular path will the block lose contact with the track? Determine this point by finding the angle θ shown in the diagram.

38 (8). In the drawing below, a block of mass m is shown suspended from a massless, inextensible string which is connected to a spring of force constant k = 800 nt/m through two massless and frictionless pulleys. The block oscillates between two points, A and B, 50 cm apart. If the tension in the string is 50 nt when the block is at point B, what is the mass of the block? (The present information will be used in the next two questions.)



39 (8). What is the speed of the block in the preceding question when it passes the point midway between A and B?

40 (8). Suppose that, at the time the block of the previous question is passing the midpoint between A and B on the upswing, the string is cut. How high does the block rise?

41 (8). The energy released by the first atomic bomb was estimated to be equivalent to that released by 20,000 tons of TNT. One ton of TNT releases about 1200 kilowatt-hours of energy. Approximately, how much mass was converted into energy in the explosion of the first atomic bomb?

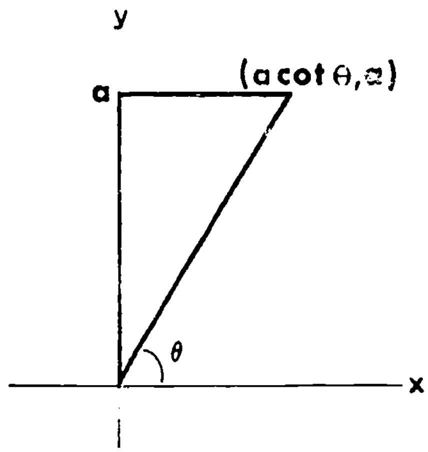
42 (8). At a certain instance the potential energy of a proton is 3.25×10^8 eV. If the proton is free to accelerate, so that its potential energy is converted into kinetic energy, what will be the proton's speed when its potential energy becomes zero? (Hint: Assume that a particle must be treated relativistically when its speed exceeds 0.1 c.)

<u>DATA:</u> 1 eV (electron volt) = 1.6×10^{-19} j.
Proton rest mass, $m_o = 1.67 \times 10^{-27}$ kg.
Speed of light $c = 3 \times 10^8$ m/sec.

43 (9). For a rigid solid body at rest, the center of mass is

A. different than it would be if the body were in motion.
B. infinitely distant from the body
C. always fixed relative to the body
D. always located at the point of the body having the highest mass density

44 (9). Calculate the y-coordinate of the center of mass of the triangular plate shown in the figure. The plate has a uniform mass-per-unit-area equal to σ.



45 (9). A 4-kg particle is traveling due north with a speed of 20 m/sec. A second particle of mass 6 kg is traveling eastward at 10 m/sec. Calculate the total kinetic energy of these two particles in their center of mass reference frame.

46 (10). For *one-dimensional motion*, Newton's second law is expressed by

$$F = \frac{d}{dt}(mv).$$

When relativistic effects are taken into account this law can be expressed as follows:

A. $F = m_o a$

B. $F = ma = \frac{m_o a}{\sqrt{1-\beta^2}}$

C. $F = \frac{m_o a}{(1-\beta^2)^{3/2}}$

D. $F = \frac{ma}{\sqrt{1-\beta^2}} = \frac{m_o a}{(1-\beta^2)}$

47 (10). A midshipman dives from aft in a stationary rowboat. His mass is 70 kg and that of the rowboat 140 kg. The horizontal component of his velocity when his feet leave the boat is 3 m/sec, relative to the water. What is the momentum of the center of mass of the system consisting of the diver and boat immediately after the dive?

48 (10). Sand is dropped onto a conveyor belt at a rate dm/dt. The external force required to keep the belt moving at constant velocity is

$\vec{F}_{ext} = \vec{v}\,\frac{dm}{dt}$. If the cost of energy is c dollars/joule, what is the cost, in dollars, for moving a total mass m?

A. cmv^2

B. $\frac{1}{2}\ cmv^2$

C. $2\ cmv^2$

D. $cv^2\ \frac{dm}{dt}$

49 (10). A billiard ball is dropped into the middle of two unequal billiard balls which are stationary on the floor, and scatters them apart. If the incident ball does not roll after impact, which of the following statements about the motion of the target balls is true?

A. The magnitude of the velocity vectors of the two masses are equal.

B. The momentum vectors of the two masses must make angles of 180° with each other.

C. None of the above.

50 (11). In a one-dimensional elastic collision of two bodies of equal mass,

A. the final velocity of either body is equal to the initial velocity of the other.

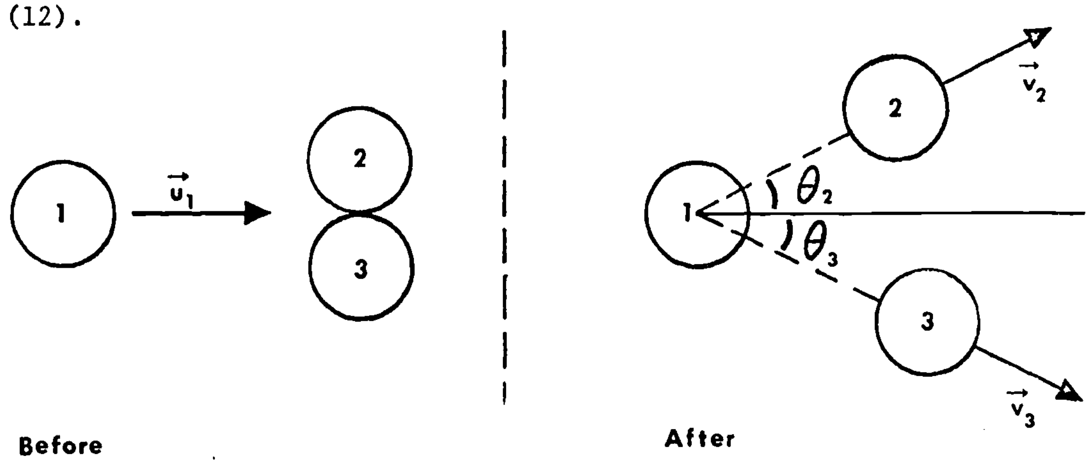
B. the final momentum of either body is equal to the initial momentum of the other body.

C. the final kinetic energy of either body is equal to the initial kinetic energy of the other body.

D. All of the above.

51 (11). A 1-ounce shell is fired with a muzzle speed of 3200 ft/sec directly at a large oak block and penetrates to a depth of 1 foot. Assuming a constant deceleration in the block, what is the magnitude of the force exerted on the shell while it is moving in the block?

52 (12).

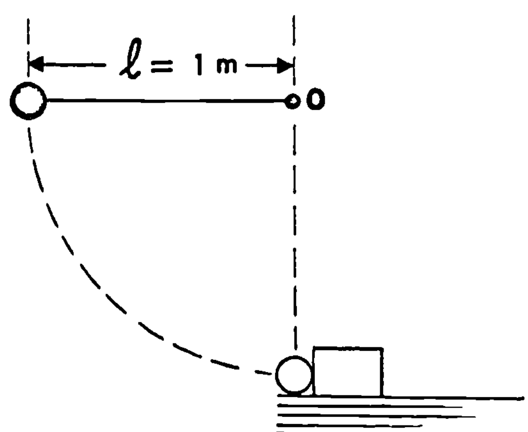


An ice hockey puck (1) is moving w[illegible] a speed u_1 in the positive x-[illegible]rection, and it collides perfectly elastically with two stationary identical pucks (2 and 3). After the collision puck 1 has come to rest, and pucks 2 and 3 are moving with velocities $\vec{v}_2$ and $\vec{v}_3$ respectively. What is the angle between $\vec{v}_2$ and $\vec{v}_3$? (The present information will be used in the next two questions.)

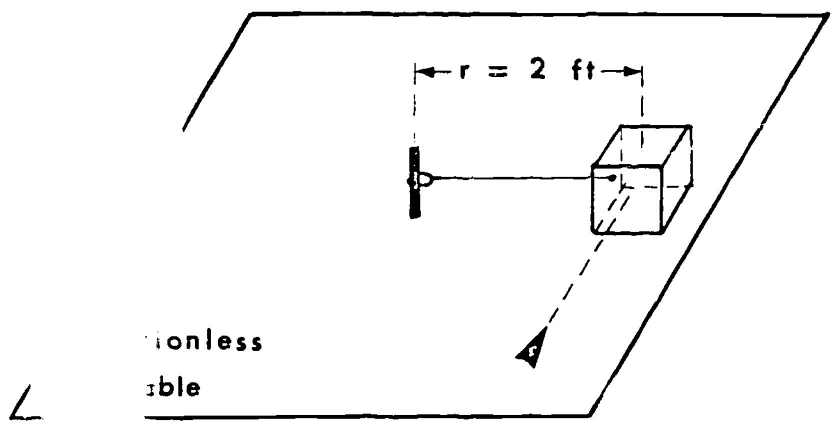
53 (12). For the collision described in the preceding problem, let $u_1 = 25$ ft/sec and $\theta_2 = 53°$. Furthermore, assume that the collision takes place on a frictionless floor. How far apart will pucks 2 and 3 be four seconds after the collision?

54 (12). Let the collision described in problem 53 (12) take place on a horizontal plane, and let the coefficient of kientic friction between the plane and the pucks be $\mu = 0.25$. If just before the collision $u_1 = 25$ ft/sec and after the collision $\theta_2 = 53°$, how far apart will the pucks be after they both come to a stop?

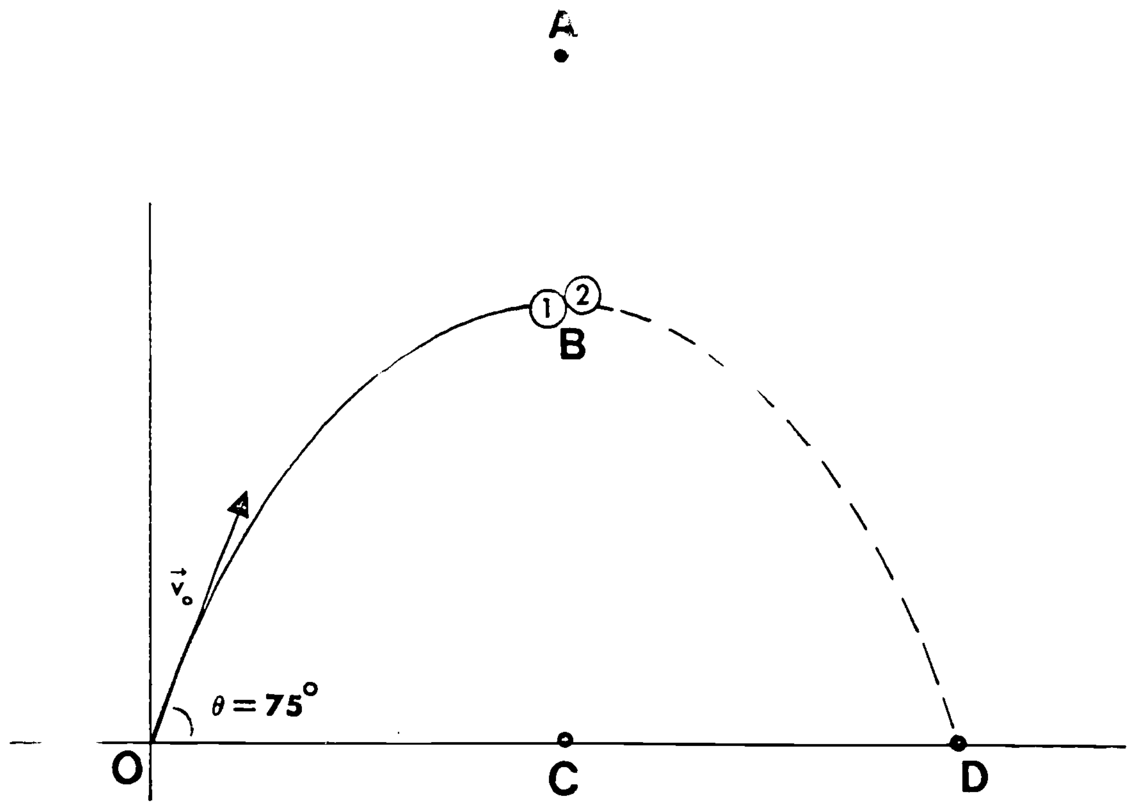
55 (12). A 3-kg steel ball is fastened to the end of a 1-m "massless" rod pivoted at point O. The rod is released when in the horizontal position and at the lowest point of the swing the ball collides perfectly elastically with a 9-kg steel block resting on a table. The coefficient of kinetic friction between the block a and the table is 0.2, while the pivot at O is frictionless. Find the distance traveled by the block on the table before coming to rest. (Neglect air resistance.)



56 (12).



A block is resti a frictionless horizontal table. The block is tied to a cord the o d of which is tied to a ring. A vertical pin fixe to the table pas rough the ring. A 1-ounce bullet with a muzzle velocity of 150 c in a direction normal to the cord strikes the block and remai dded in it. If the maximum tension that the cord can withstand is , what is the minimum weight that the block can have in order that e cord does not break?



Ball 1 is projected from the origin with initial velocity of 80 ft/sec at 75° above the horizontal (see diagram above). At the same time an identical ball (2) is released from point A with zero initial velocity. The two balls collide perfectly elastically at point B at the moment ball 1 reaches its highest altitude and some time later ball 1 hits the ground at point C such that points A, B, and C lie on a vertical line. Finally ball 2 hits the ground at point D. How far is point D from the origin? (Hint: Treat the two balls as point particles.)

58 (12). Us[illegible] s of the particles inv[illegible]

m_p = [illegible] 10^{-27} kg,

[illegible] = [illegible] 10^{-27} k[illegible] and

[illegible] = [illegible] 10^{-27} kg,

to calculate t[illegible] [illegible]e following nuclear rea[illegible]on.

[illegible] → $\alpha_1 + \alpha_2$ [illegible];

where K_1 re[illegible] total k[illegible]net[illegible] energy be[illegible]re the colli[illegible]n and K_2 the total kinetic [illegible]y after the [illegible]lision. [illegible] the Li^7 nu[illegible]s is assumed stationary [illegible] K_1 is the ki[illegible]tic energy of the prot[illegible] In the above reaction there [illegible] actually an [illegible]ermediate nucleus for[illegible], that of Beryllium (B_e^8). [illegible]er, B_e^8 [illegible]s a [illegible] loosely bound nucle[illegible] [illegible]nd the released energy i[illegible] [illegible]gh to break i[illegible] [illegible]to two alphas.

The energy of the above reaction (net energy released) is given by

$Q =$ [illegible] $- K$ [illegible] $K_{\alpha 1} + K_{\alpha 2} - K_p$

For convenience [illegible] shall use the followin subscripts:

α [illegible] alpha particle (H_e^4)

p [illegible]or t[illegible] proton (H^1), and

ℓ f[illegible] the [illegible]ithium seven nucleus (Li^7).

59 (12). In the [illegible]eceding problem we found that the net energy released in the nuclear reaction

$p + Li^7$ → $2\alpha + Q$

is Q = 2.77 × 10^{-12} [illegible]. Assuming that the target Li^7 nucleus is at rest and that the incoming proton's energy is negligible compared to Q, calculate the speeds of the two α-particles after the reaction.

60 (12). Consider the reverse (endothermic) reaction

[illegible] + [illegible] − Q' → $p + Li^7$

where Q' is the energy that must be supplied [illegible] the reaction to take place. In problem 58 (12) we found that when Li^7 [illegible] bombarded with protons the energy released, Q, is 2.777 × 10^{-12} . If in the reaction above one of the α-particles is stationary, what must be the threshold (minimum) kinetic energy of the incident α-particle in order that the reaction take place?

61 (13). Kepler was able to formulate his [illegible] f planetary motions from data supplied by

A. Ptolemy
B. Copernicus
C. Tycho Brahe
D. Galileo

62 (13). Of the following statements, [illegible] ne one which best represents Kepler's first law of planetary mo[illegible].

A. A line joining any planet to th[illegible] sweeps out equal areas in equal times.

B. The square of the period of an[illegible] [illegible]net about the sun is proportional to the cube of the planet's mean distance from the sun.

C. All planets move in elliptical [illegible] having the sun as one focus.

D. The force of attraction between the sun and each planet is along the line joining the two and has magnitude which is proportional to the product of their masses and inversely proportional to the square of the distance between them.

63 (13). Pluto is the most distant of the nine planets from the sun. Its mean orbital radius is 5.9×10^9 km, as compared to 0.15×10^9 km for the Earth's mean orbital radius. Determine the relation between an Earth year and a Pluto year.

64 (13). Of the four choices, select the one which makes the statement . . . Newton's law of universal gravitation enabled us to

A. derive Kepler's three laws of planetary motion

B. answer the question "Why do bodies attract each other?"

C. synthesize terrestrial and celestial mechanics into a single theory

D. calculate the acceleration of gravity near the surface of the Earth.

65 (13). The universal gravitational constant, G

A. may be computed from theory

B. must be determined experimentally

C. is only correct near the surface of the Earth

D. is proportional to the square of the distance between the masses involved.

66 (13). Assume that gravitational (primed) and inertial (unprimed) masses are not the same, and define

$$g' \equiv \frac{GM_e'}{R_e^2}$$

What is the "acceleration of gravity" at the surface of the Earth for a particle of inertial mass m whose gravitational mass is m'?

A. $\frac{GM_e'}{R_e^2}$

B. $\frac{GM_e}{R_e^2}$

C. $\frac{m}{m'} g'$

D. $\frac{m'}{m} g'$

-- 13). For a per... spher.cal Earth of radius 6.37×10^6 m with axis through b... s. How much more ...es a 70-kg man weigh at a ...tude of 37° than ...es at the equato... (Assume the weighing to be ... with a "massless ...ring balance.)

6: (13). Newton's law ... universal gr... itation, $F = G\, m_1 m_2/r^2$, was formulated for point masses ...rticles). How... ver it also applies to certain extended bodies if m_1 a... m_2 are taken ... be the masses of the bodies involved, and r the dis... ce between th... geometric centers. Of the following four classes, select the most ... sive class of bodies to which Newton's law of universal gravitat... applies.

A. All spheres w... uniform mass ...tribution

B. All spheres whose mass density ... a function of the distance from the center

C. All spheres

D. All solids ... revolution having ur...rm mass distribution

69 (14). Sa...'s equatorial radius is 60,400 km and the period of its rotation about ...s axis is 10 hrs, 14 min. What is the apparent weight of a 10-kg mass at a point on the Saturn's equator if the gravitational field strength ... ere is $\gamma = 10.5$ m/sec^2?

... (14). The gravitational potential as ... function of distance, r, from the center of a uniform spherical shell of radius R and mass M is given by

A. $-\frac{GM}{r}$ everywhere

B. $-\frac{GM}{R}$ for $r<R$; $-\frac{GM}{r}$ for $r>R$

C. 0 for $r<R$; $-\frac{GM}{r}$ for $r>R$

D. $-\frac{GMr}{R^2}$ for $r<R$; $-\frac{GM}{r}$ for $r>R$

71 (14). The gravit [illegible] tial as a function [illegible] distance, r, from the center of a unifo[illegible]-density sphere of [illegible]ius R and mass M given by

A. $-\frac{GM}{r}$ everywhere

B. $-\frac{GM}{R}$ for r<R; $-\frac{GM}{r}$ for r>R

C. $-\frac{GMr^2}{2R^3}$ for r R; $-\frac{GM}{r}$ for r>R

D. $\frac{GMr^2}{2R^3} - \frac{3}{2}\frac{GM}{R}$ for r<R; $-\frac{GM}{r}$ for r>R

72 (14). The choi[illegible] made earlier for the gravitational potential energy of a mass m at a distance y from the surface of the Earth, U = mgy, is valid

A. only near [illegible] above the surface of the Earth, with the reference [illegible]sition for zero potential taken at infinity

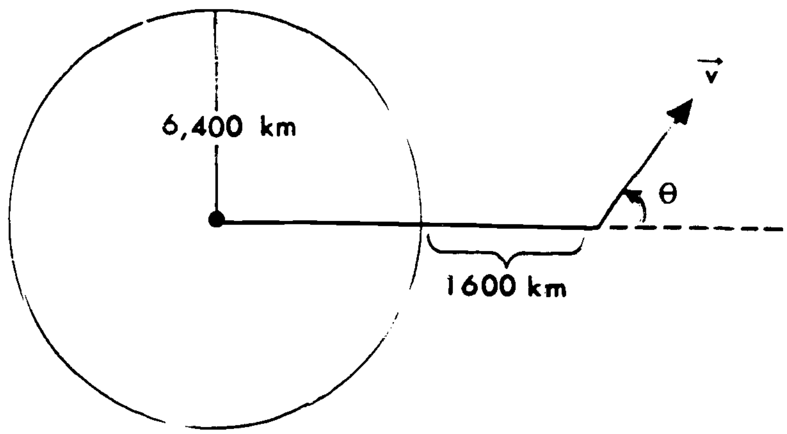
B. at any poin[illegible] in space

C. only [illegible]ear a[illegible]d above the surface of the Earth, [illegible]th the Eart[illegible]s sur[illegible]ace taken as the zero potential reference

D. only f[illegible]r particles near and above the surface o[illegible] the Earth and for particles below the surface of the Eart[illegible] no matter how deep, provided the Earth's surface is taken as the zero potential reference

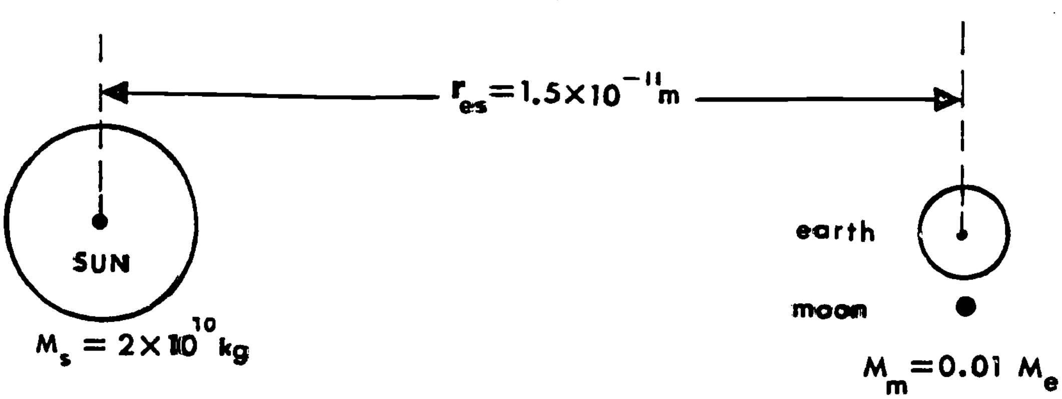
7[illegible] (14). Suppose a rocket blasts off and achieves its maximum velocity, v_c = [illegible] km/sec, instantaneously. What is the height (measured from the Earth's surface) of maximum ascent of the rocket? Neglect air resistance.

74 (14). At an altitude of 1,600 km above the Earth's surface, the escape speed is 10 km/sec. In order that a rocket at this altitude with this speed actually escape the Earth's gravitational field, the largest angle which its velocity vector can make with the line from the Earth's center is (see diagram)



A. zero
B. 90°
C. an angle between 90° and 180°
D. 180°

75 (14). Suppose that an outside agent were momentarily to stop the moon in its orbit about the Earth and sun; that is, bring it to rest with respect to the sun and then give it a swift kick toward the Earth. What speed must the agent impart to the moon, setting it in motion directly toward the Earth, in order to thereby knock the Earth-moon system out of the solar system? Assume that the collision between the Earth and the moon is totally inelastic, and that the sun-Earth-moon configuration is as in the diagram. (The average speed of the Earth-moon system in its orbit about the sun is 3.4×10^4 m/sec.)



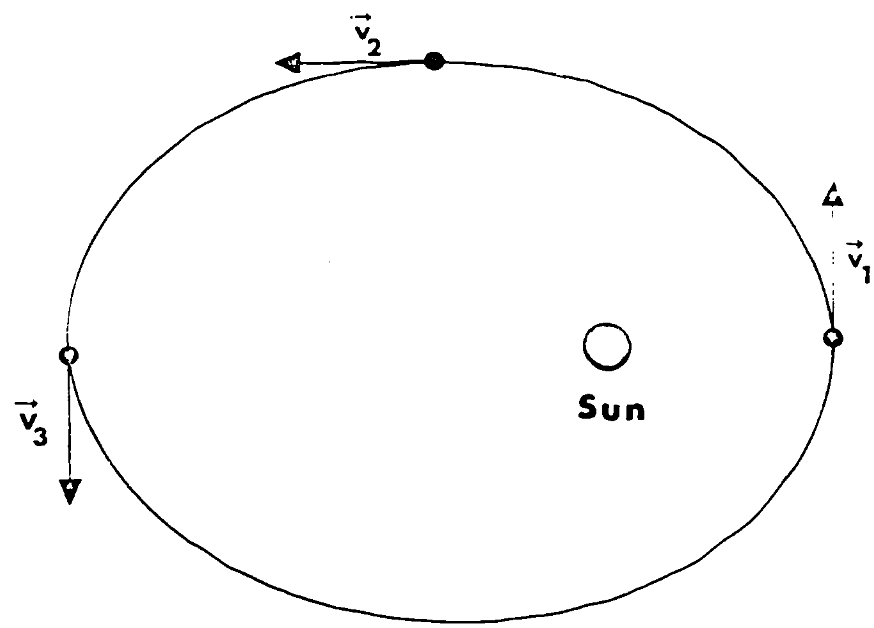
76 (1-/. An Earth satellite at a moderate altitude in circular orbit will lose energy because of air resistance. The rate at which energy is lost is slow enough so that successive orbits can be approximated by circles of slightly differing radii. What will be the altitude of a 1,000-kg satellite after it does 9×10^8 j of work against air friction, if its initial altitude was 270 km? Assume circular orbits and take $R_e = 6,400$ km, $G = 6.67 \times 10^{-11}$ ntm^2/kg^2 and $M_e = 6 \times 10^{24}$ kg. (This information will be used in the following question as well.)

77 (14). What are the initial and final speeds of the satellite in the previous question?

78 (14). What would be the length of the day if the Earth's rotation rate were such that masses were weightless at the equator? Take $g = 9.78$ m/sec^2 and $\gamma = 9.81$ m/sec^2 at the equator, and $R_e = 6.37 \times 10^6$ m.

79 (14). What would be the period of a space platform in circular orbit just above the surface of the moon? Use $R_m = 1,700$ km, and $M_m = 8 \times 10^{22}$ kg.

80 (14). Refer to the following diagram of an elliptic planetary orbit about the sun. (The eccentricity has been somewhat exaggerated.)



Which is the correct relationship between the orbital speeds of a planet at the three positions shown?

A. $v_1 > v_2 > v_3$

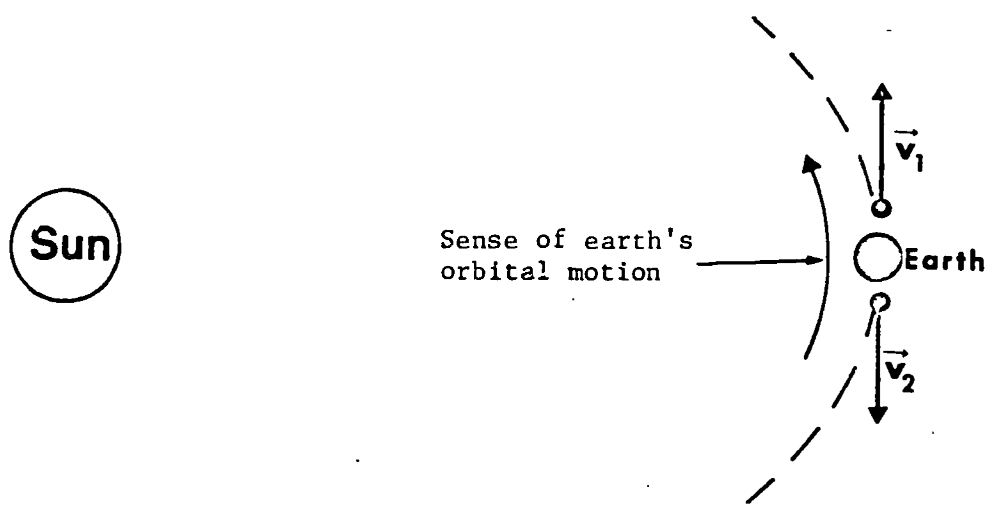
B. $v_1 = v_3 < v_2$

C. $v_3 > v_2 > v_1$

D. $v_1 = v_3 > v_2$

81 (14). At what distance from the Earth along the line of the sun is the gravitational field strength equal to zero? Use $M_s = 3.3 \times 10^5\ M_e$, $r_{es} = 1.5 \times 10^{11}$ m, and neglect other members of the solar system.

82 (14). The escape speed from the surface of the Earth is 11.2 km/sec; that from the sun at the position of the Earth's orbit is 42 km/sec. The mean orbital speed of the Earth about the sun is 29.8 km/sec. Two rockets are fired from the Earth's surface, tangent to the Earth's orbit, in opposite directions. Each has a speed of 15 km/sec relative to the Earth. Neglecting the effects of other members of the solar system and air resistance, and referring to the accompanying diagram, select the statement which best describes the fate of the two rockets.



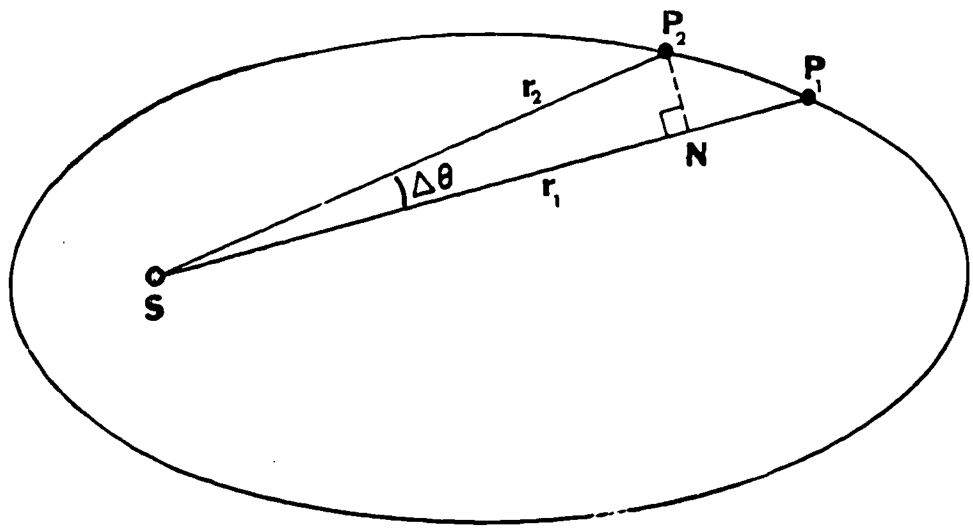
A. Both rockets will escape the solar system.

B. Rocket 1 will escape the solar system; rocket 2 will go into an elliptical orbit about the sun.

C. Rocket 1 will escape the solar system; rocket 2 will return to the Earth.

D. Rocket 1 will go into an elliptical orbit about the sun; rocket 2 will return to the Earth.

83 (14). We wish to derive the mathematical statement of Kepler's second law that a line joining a planet to the sun sweeps out equal areas in equal times. Referring to the diagram, let the planet travel from P_1 to P_2 in time Δt. Calculate the area ΔA swept out in this time interval. Approximate the arc P_1P_2 to a straight line, but make no other approximations.



A. $\frac{1}{2} r_2^{\ 2} \sin\Delta\theta \cos\Delta\theta$

B. $\frac{1}{2} r_1^{\ 2} \Delta\theta$

C. $\frac{1}{2} r_1 r_2 \sin\Delta\theta$

D. $\frac{1}{2} r_1 r_2 \Delta\theta$

84 (14). In the previous question (page 33), we found that the area swept out in a short time Δt by the radius vector from the sun to a planet is $\Delta A = (1/2)\ r_1\ r_2\ \sin\Delta\theta$.

State Kepler's second law in mathematical form. (Hint: Recall that the definition of angular velocity is $\omega \equiv d\theta/dt$.)

A. $\frac{dA}{dt} = \frac{1}{2}\ r^2\omega^2$

B. $\frac{dA}{dt} = \frac{1}{2}\ r^2\omega\ \cos\theta$

C. $\frac{dA}{dt} = \frac{1}{2}\ r^2\omega = \text{constant}$

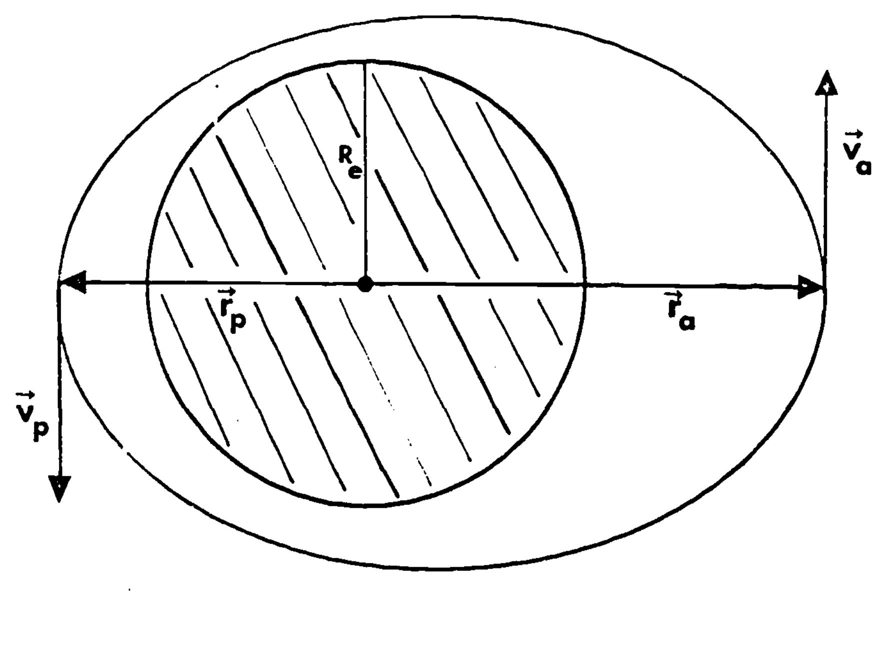
D. $\frac{dA}{dt} = \frac{1}{2}\ r^2\ \sin\omega = \text{constant}$

85 (14). What is the ratio of the angular speed of the Earth (actually, of the center of mass of the Earth-moon system) about the sun at perihelion to that at aphelion? The distances from the sun are respectively

$$r_p = 1.47 \times 10^{11}\ \text{m}$$

$$r_a = 1.52 \times 10^{11}\ \text{m}$$

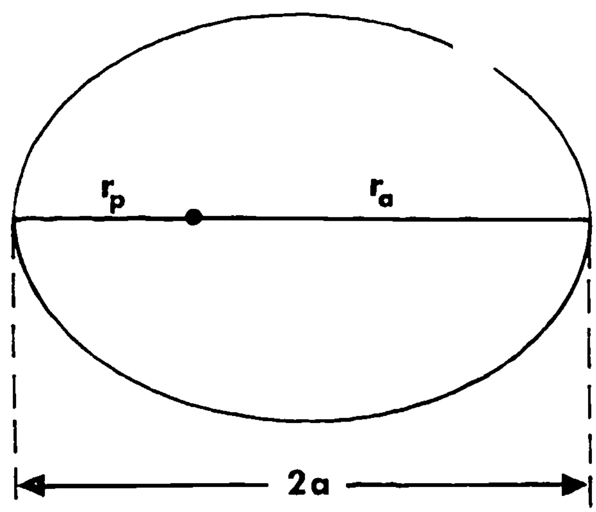
86 (14). The first artificial Earth satellite, Sputnik I, had a perigee and apogee of approximately 6,600 and 7,300 km, respectively. Use Kepler's second law and conservation of energy to derive its speeds at perigee and apogee. (Hint: At perigee and apogee the velocity vector is perpendicular to the radius vector, $|\vec{v}| = |\vec{\omega} \times \vec{r}| = \omega r$.)



87 (14). Kepler's third law for the special case of circular orbits is expressed as

$$T^2 = \frac{4\pi^2}{GM_e} r^3$$

In the general case of elliptical orbits, the same equation holds if the radius of the circular orbit, r, is replaced by the semi-major axis of the ellipse, a.



Use the data given in the previous question; namely r_p = 6,600 km, r_a = 7,300 km, to calculate the period of Sputnik I.